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RESPONSE OF DUCKS TO GLYPHOSATE-INDUCED HABITAT ALTERATIONS IN WETLANDS

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Abstract: The effects of glyphosate herbicide-induced changes in wetland emergent vegetation (largely cattails, *Typha* spp.) on densities of ducks (Anatinae) were assessed in northeastern North Dakota. In 1990 and 1991, 17 cattail-dominated wetlands were randomly assigned to 0% (reference wetlands), 50%, 70%, or 90% areal spray coverages with glyphosate herbicide. Densities of green-winged teal (*Anas crecca*), blue-winged teal (*Anas discors*), gadwalls (*Anas strepera*), and ruddy ducks (*Oxyura jamaicensis*) were similar among treatments during both post-treatment years ($P \geq 0.1$). One year post-treatment, mallard (*Anas platyrhynchos*) and northern pintail (*Anas acuta*) abundances did not differ among treatments ($P \geq 0.1$), whereas two years post-treatment their abundances were greater in the sprayed wetlands than in the reference wetlands ($P \leq 0.1$). Densities of northern shovelers (*Anas clypeata*) and redheads (*Aythya americana*) differed among treatments in both post-treatment years, with the 50% sprayed wetlands harboring more ducks than did the other three treatments. Percent coverage and hectares of open water were positively correlated with numbers of diving ducks (Aythyini and Oxyurini) ($P \leq 0.1$). Dabbling duck (Anatini and Cairinini) numbers correlated positively with hectares of open water and dead vegetation, whereas their numbers were negatively correlated with percent coverage of live vegetation ($P \leq 0.1$). Results of this study suggest that numbers of ducks were positively influenced by creating a mosaic of open water, live vegetation, and dead vegetation with glyphosate herbicide.

Key Words: cattails, dabbling ducks, diving ducks, glyphosate, waterfowl, wetlands, habitat management, Typha

INTRODUCTION

Wetlands in the Prairie Pothole Region of the United States are often dominated by common cattail (*Typha latifolia* L.), narrow-leaved cattail (*T. angustifolia* L.), and their hybrid *T.* × *glauca* Godron. Cattails are the most common large hydrophyte in North Dakota wetlands (Kantrud 1986). Cattails that form dense homogenous stands impede waterfowl use of the wetland (Kantrud 1986), and dense cattail stands near grain crops provide migrating blackbirds (Icterinae) ideal roosting locations (Linz et al. 1995). Emergent vegetation interspersed with open water may benefit waterfowl (Kaminski and Prince 1981, Murkin et al. 1982, Kantrud 1986, Solberg and Higgins 1993) and may deprive blackbirds of an essential roost habitat (Linz et al. 1995).

Experiments conducted with small plots suggested that an equal interspersion of vegetation and open water is preferred by waterfowl (Kaminski and Prince 1981, Murkin et al. 1982). Solberg and Higgins (1993) demonstrated that wetlands treated with a single strip or a single crossing pattern of glyphosate herbicide harbored more ducks (Anatinae) than reference wetlands. To our knowledge, experimental data on the response of ducks to cattail-dominated wetlands altered with various spray coverages of aquatic herbicides is lacking.

In North Dakota and South Dakota, cattail-dominated wetlands that harbor roosting blackbirds are being fragmented by aerially applying glyphosate to achieve open water—emergent vegetation ratios ranging from 50:50 to 90:10 (Huffman 1992, Linz et al., 1995). In this paper, we compare densities of ducks among wetlands treated with various herbicide spray coverages to reference wetlands and describe the relationships between duck abundance and various wetland habitat variables.

STUDY AREA AND METHODS

Our study area was near Lakota, North Dakota (48° 03′N, 98° 21′W) in Grand Forks, Nelson, and Walsh counties of northeastern North Dakota. The study area is located in the Northeastern Drift Plain of North Dakota, which is characterized by the presence of many wetlands that are subject to large annual variations in water coverage (Stewart and Kantrud 1973). The primary land use is growing of small grains, sunflower, hay, and corn. North Dakota receives 77% of its annual precipitation between April and September (North Dakota Agricultural Statistics Service 1994). Long-term average monthly precipitation and temperature during these months are about 5.4 cm and 14.6° C, respectively (North Dakota Agricultural Statistics Service 1994).

In May 1990, we randomly designated a pool of 12 cattail-dominated wetlands, as either reference or treated at 70% or 90% spray coverage with aerially applied glyphosate herbicide (Rodeo® formulation, Monsanto Company, St. Louis, Missouri). In May 1991, we randomly designated another 12 wetlands as either reference or treated at 50% or 70% spray coverage with glyphosate. A 50% spray coverage level was substituted for the 90% spray coverage used in 1990. This substitution was suggested by wetland managers concerned about inadequate cover for wildlife in wetlands treated at the 90% level (Stromstad 1992). Five wetlands that had ≥ 25% open water (Solberg and Higgins 1993) and two wetlands that were dry were not included in the data set. Statistical analyses were conducted with the following data set: reference (n = 5), 50% (n = 3), 70% (n = 6) and 90% (n = 3) spray coverages. Average size of the 17 experimental wetlands was 11.4 ± 2.7 (SE) ha.

The wetlands were treated in mid- to late July at a rate of 5.8 l/ha of glyphosate (Blixt 1993, Linz et al. 1994). The herbicide was mixed in an aqueous solution containing surfactant, drift retardant, and water (Linz et al. 1994). A fixed-wing spray plane was used to apply 15-m-wide parallel strips of herbicide along the long axis of the wetlands.

Wetland sizes and coverages of open water and vegetation were determined from aerial photographs using Map and Image Processing System software (MicroImages, Inc., Lincoln, NE). Ektachrome photographs, taken in June 1990, were obtained from the Agricultural Stabilization and Conservation Service for habitat analysis of 1990 wetlands; however, vegetation type could not be distinguished on these slides. In August 1991–93, color infrared slides were taken of the test wetlands. Species of vegetation were identified by color differences on the photographs and verified by ground truthing. In 1991, vegetation types could not be distinguished in the 1991-treated wetlands because the vegetation had begun to show the effects of the herbicide treatment.

Birds were counted on the experimental wetlands once before treatment (pretreatment) and for two years after treatment (post-treatment). During 2–18 June, wetlands were visited in random order between local sunrise and 5-hr post-sunrise by one or two observers in 1990 and two of three observers in 1991–1993. Counts were made by the same pool of three experienced observers throughout the study.

In 1990, the observer(s) slowly walked around the perimeter of the wetlands and recorded all ducks (regardless of sex) on or flushed from the wetland. In 1991, we established eight count points at uniform intervals around the perimeter of each wetland (Hutto et al. 1986, Linz et al. 1994). The same count points were used from 1991 through 1993. The observers walked to each count point and recorded all ducks seen on the water or leaving the wetland during the next six minutes. Any ducks seen or flushed while the enumerators moved between count points were tallied.

During June 1992, the reference, 70% sprayed, and 90% sprayed wetlands were visited in random order between local sunrise and 5-hr post-sunrise by two observers not involved in the fixed-point counts. These observers waded through the wetlands and counted all ducks spotted or flushed from the wetland. The fixed-point counts and flush counts were conducted on different days. Densities of ducks detected by these two count methods were similar within the 5 reference wetlands (Wilcoxon Test, P = 0.346) (Cody and Smith 1991) and over all 14 wetlands (P = 0.646), averaging 2.42 ± 0.62 ha and 3.14 ± 0.45 ha, respectively. Thus, the potential visibility bias inherent in the fixed-point count method appears to be minimal. Censuses were not conducted in steady rain or if the wind velocity exceeded 24 km/hr.

STATISTICAL ANALYSES

A one-factor analysis of variance (ANOVA) was used to compare percent coverages of open water and vegetation among wetlands designated for various treatment levels (Cody and Smith 1991). A two-factor repeated measure ANOVA (RMANOVA) was used to test the null hypotheses of no differences in percent coverage of open water, live vegetation, and dead vegetation among spray coverages one and two years post-treatment (Cody and Smith 1991).

We conducted statistical analyses on selected species of dabbling ducks (Anatini and Cairinini) and diving ducks (Aythyini and Oxyurini) present on ≥ 50% of the wetlands during at least one post-treatment year. The count data for each duck species and taxonomic group were divided by the size of the wetland to obtain the number of birds per hectare. Kruskal-Wallis tests were used to examine the null hypotheses that average densities of each duck species and taxonomic group within each test year were similar among treatments (Conover 1980, Cody and Smith 1991). Numbers of ducks using the test wetlands were compared between experiment years with the Wilcoxon test (Conover 1980, Cody and Smith 1991).

We investigated the relationship between the mean number of ducks (dependent variable) observed in each wetland during the two post-treatment years and hectares of live vegetation, dead vegetation, and open water (independent variables) using Spearman rank correlation analysis (Cody and Smith 1991). Similarly, correlation analysis was used to assess the relationship between duck numbers and percent coverages of water, live vegetation, and dead vegetation. We set the significance level at 0.1 (*a priori*) for all statistical tests because resources were not sufficient to increase sample sizes, and the consequences of accepting false null hypotheses (Type II error) on populations of ducks are much greater than if Type I errors (rejecting a true null hypothesis) are made (Tacha et al. 1982).

RESULTS

Habitat Characteristics

Before the application of glyphosate, percent coverages of open water ($\bar{x}$ = 11.8 ± 1.7 [SE] %) and emergent vegetation ($\bar{x}$ = 88.2 ± 1.7%) were not significantly different (P = 0.723) among treatments (Figure 1).

Percent coverage of open water was greater (P = 0.001) two years post-treatment ($\bar{x}$ = 33.3 ± 4.1%) than one year post-treatment ($\bar{x}$ = 16.9 ± 2.8%). Coverage of open water was greater in the sprayed wetlands ($\bar{x}$ = 30.4 ± 3.0%) than in the reference wetlands ($\bar{x}$ = 12.3 ± 4.3%) during these years (P = 0.014).

Coverage of live vegetation differed (P = 0.040) between one year post-treatment ($\bar{x}$ = 38.6 ± 7.0%) and two years post-treatment ($\bar{x}$ = 44.3 ± 4.6%). In these years, the coverage of live vegetation was greater (P = 0.0004) in the reference wetlands ($\bar{x}$ = 70.3 ± 4.1%) than in the sprayed wetlands ($\bar{x}$ = 29.4 ± 3.3%).

Percent coverage of dead vegetation was greater (P = 0.0003) one year post-treatment ($\bar{x}$ = 44.5 ± 5.4%) than two years post-treatment ($\bar{x}$ = 22.4 ± 3.0%). During this time, the coverage of dead vegetation was greater (P = 0.006) in the sprayed wetlands ($\bar{x}$ = 40.2 ± 4.2%) than in the reference wetlands ($\bar{x}$ = 17.3 ± 3.2%).

Response of Ducks

Before treatment, the 17 test wetlands harbored 197 dabbling ducks and six diving ducks. Mallards (*Anas platyrhynchos* L.) and blue-winged teal (*A. discors* L.) each made up 31% of the total number of ducks, followed by 21% gadwalls (*A. strepera* L.), 5% wood ducks (*Aix sponsa* L.), 4% green-winged teal (*Anas crecca* L.), 3% northern pintails (*A. acuta* L.), 2% northern shovelers (*Anas clypeata* L.), 2% redheads (*Aythya americana* Eyton), and < 1% ruddy ducks (*Oxyura jamaicensis* Gmelin). Mallards, blue-winged teal, and gadwalls were the only species found on ≥ 50% of the test wetlands. Densities of mallards ($\bar{x}$ = 0.53 ± 0.16 ha), blue-winged teal ($\bar{x}$ = 0.64 ± 0.21 ha), gadwalls ($\bar{x}$ = 0.32 ± 0.09 ha), and dabbling ducks ($\bar{x}$ = 1.66 ± 0.41 ha) did not differ among the three treatments before treatment (P range = 0.516–0.837).

During the two post-treatment years, the test wetlands contained 782 dabbling ducks and 244 diving ducks. Blue-winged teal made up 31% of the total number of ducks, followed by 17% mallards, 15% redheads, 10% gadwalls, 7% ruddy ducks, 7% northern shovelers, 4% northern pintails, 4% green-winged teal, 3% wood ducks, 2% canvasbacks (*Aythya valisineria* Wilson), < 1% ring-necked ducks (*A. collaris* Donovan), < 1% American wigeon (*Anas americana* Gmelin), and < 1% lesser scaup (*Aythya affinis* Eyton).

Blue-winged teal, mallards, redheads, gadwalls, northern shovelers, ruddy ducks, northern pintails, and green-winged teal were observed on ≥ 50% of the wetlands during at least one post-treatment year. Densities of all these species were statistically similar across post-treatment years (P range = 0.251–0.751). Densities of green-winged teal, blue-winged teal, gadwalls, and ruddy ducks were similar (P range = 0.109–0.715) among treatments during both post-treatment years (Tables 1 and 2). The first year after treatment,

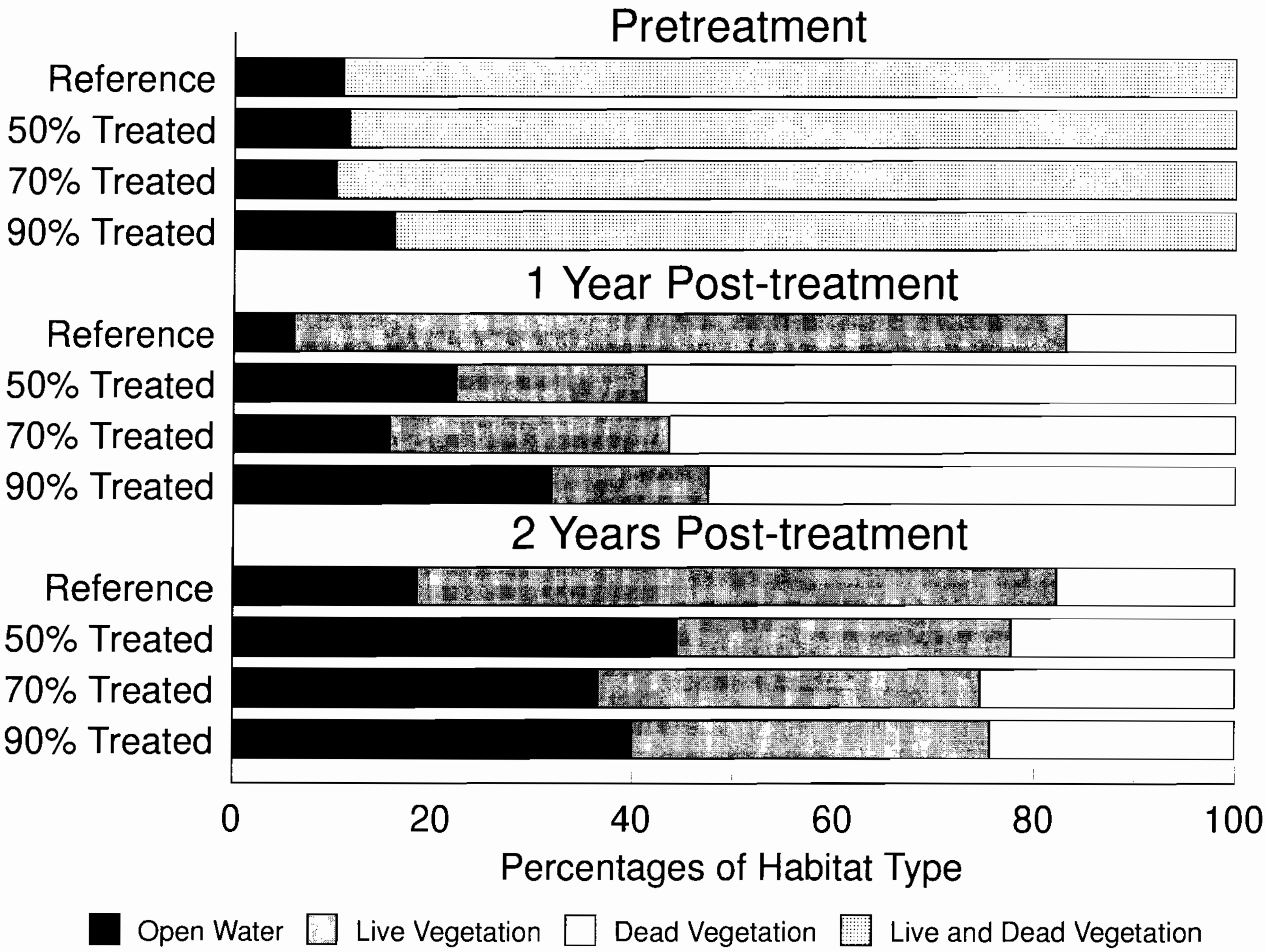

Figure 1. Habitat characteristics of 17 wetlands randomly designated as either reference (n = 5), or treated at 50% (n = 3), 70% (n = 6) or 90% (n = 3) spray coverage with glyphosate herbicide during July 1990 and 1991 in northeastern North Dakota.

mallard (P = 0.143) and northern pintail (P = 0.491) abundances did not differ among treatments (Table 1). During the second year post-treatment, density of mallards differed among treatments (P = 0.046), with more birds in the 50% and 90% wetlands than in the 70% and reference wetlands. Northern pintail (P = 0.053) densities differed among treatments, with more birds in the sprayed wetlands than in the reference wetlands (Table 2). Densities of northern shovelers (P range = 0.047–0.087) and redheads (P range = 0.050–0.070) differed among treatments in both post-treatment years, with the 50% sprayed wetlands containing more ducks than did the other three treatments (Table 1, 2).

Waterfowl-Habitat Relationship

During the post-treatment years, the number of mallards, blue-winged teal, northern shovelers, redheads, ruddy ducks, total diving ducks, and total ducks were correlated positively with hectares of open water (r range = 0.422–0.568) and percent coverage of open water (r range = 0.305–0.393). Gadwalls, northern pintails, and dabbling ducks were only correlated with hectares of open water (r range = 0.294–0.420) (Table 3).

Mallards, blue-winged teal, northern shovelers, gadwalls, northern pintails, dabbling ducks, and total ducks were negatively correlated with percent coverage of live vegetation [(r range = −0.360–(−0.490)] and were correlated positively with hectares of dead vegetation (r range = 0.302–0.474). Hectares of live vegetation and percent coverage of dead vegetation were not significantly correlated with any taxon during the post-treatment years (P > 0.1).

DISCUSSION

Results of this field experiment suggest that numbers of ducks were positively influenced by reducing

Table 1. Densities[1] of ducks using wetlands during June in northeastern North Dakota one year after treatment with glyphosate herbicide. Treated wetlands were aerially sprayed in July 1990 and 1991.

	Spray Coverages								
	Reference $n = 5$		50% $n = 3$		70% $n = 6$		90% $n = 3$		
Ducks[2]	x̄	SE	x̄	SE	x̄	SE	x̄	SE	*P*
Green-winged teal	0.20	0.13	0.14	0.01	0.24	0.12	0.00	0.00	0.302
Mallard	0.34	0.10	1.08	0.41	0.33	0.08	0.28	0.10	0.143
Northern pintail	0.07	0.06	0.10	0.05	0.03	0.02	0.19	0.14	0.491
Blue-winged teal	0.55	0.19	2.27	1.31	0.85	0.23	0.58	0.41	0.422
Northern shoveler	0.00	0.00	0.50	0.12	0.20	0.09	0.15	0.15	0.047
Gadwall	0.23	0.10	0.57	0.04	0.53	0.20	0.32	0.18	0.483
Redhead	0.31	0.14	0.80	0.41	0.32	0.22	0.00	0.00	0.070
Ruddy duck	0.07	0.07	0.27	0.11	0.19	0.12	0.00	0.00	0.109
Dabbling ducks	1.52	0.49	4.68	1.81	2.28	0.37	1.53	0.97	0.129
Diving ducks	0.30	0.20	1.11	0.56	0.58	0.29	0.00	0.00	0.093
Total ducks	1.90	0.54	5.78	2.34	2.86	0.48	1.53	0.97	0.147

[1] Number of ducks per hectare.
[2] Ducks observed on at least 50% of the wetlands during at least one post-treatment year.

the density of live emergent vegetation (i.e., cattails). It appears the 50% sprayed wetlands were favored by ducks over the other three treatment levels, and sprayed wetlands harbored more ducks than did the reference wetlands. Openings may have enabled us to better see ducks in the sprayed wetlands compared to the reference wetlands. However, this does not explain why more ducks were counted in the 50% sprayed wetlands than in the 70% sprayed and 90% sprayed wetlands. Additionally, numbers of ducks observed in our reference wetlands with the 'walk-wade' method were statistically similar to numbers of ducks detected with the fixed-point count technique. However, we recognize the fixed-point count method potentially could result in counts that are biased low in large wetlands containing dense stands of emergent vegetation.

High variability in the duck counts within treatment levels and between years indicates that environmental factors other than coverage of water and emergent vegetation are important to ducks. For example, the size and depth of the wetland and its juxtaposition to other wetlands may be important selection factors for waterfowl (Brown and Dinsmore 1986). The number of open pools also may be a factor influencing duck abundance (Weller and Fredrickson 1974).

We found that dabbling duck abundances were high-

Table 2. Densities[1] of ducks using wetlands during June in northeastern North Dakota two years after treatment with glyphosate herbicide. Treated wetlands were aerially sprayed in July 1990 and 1991.

	Spray Coverages								
	Reference $n = 5$		50% $n = 3$		70% $n = 6$		90% $n = 3$		
Ducks[2]	x̄	SE	x̄	SE	x̄	SE	x̄	SE	*P*
Green-winged teal	0.12	0.06	0.29	0.29	0.00	0.00	0.19	0.10	0.176
Mallard	0.21	0.09	1.88	0.75	0.16	0.06	1.02	0.49	0.046
Northern pintail	0.00	0.00	0.32	0.11	0.19	0.17	0.48	0.36	0.053
Blue-winged teal	0.81	0.45	2.11	0.30	0.89	0.26	1.22	0.40	0.133
Northern shoveler	0.10	0.08	0.71	0.18	0.23	0.10	0.17	0.08	0.087
Gadwall	0.38	0.24	0.67	0.38	0.24	0.10	0.19	0.15	0.715
Redhead	0.09	0.04	1.78	0.36	0.32	0.13	1.07	0.72	0.050
Ruddy duck	0.04	0.04	0.36	0.18	0.26	0.18	0.74	0.49	0.154
Dabbling ducks	1.99	0.96	6.16	0.84	1.99	0.31	3.30	1.26	0.087
Diving ducks	0.13	0.04	2.51	0.32	0.81	0.46	1.81	1.21	0.096
Total ducks	2.12	0.95	8.68	0.64	2.80	0.68	5.11	2.13	0.044

[1] Number of ducks per hectare.
[2] Ducks observed on at least 50% of the wetlands during one post-treatment year.

Table 3. Spearman correlations describing the relationship between the mean number of ducks found in 17 wetlands during June in northeastern North Dakota one and two years post-treatment and coverages of three wetland habitat variables. Wetlands were aerially sprayed with glyphosate herbicide in July, 1990 and 1991.

	Habitat Variable					
	Water		Live Emergent Vegetation		Dead Emergent Vegetation	
	r		*r*		*r*	
Taxon[1]	Percentage	Hectare	Percentage	Hectare	Percentage	Hectare
Mallard	0.368**	0.568***	−0.377**	0.218	0.096	0.459***
Green-winged teal	−0.220	−0.090	−0.109	−0.194	0.276	0.071
Blue-winged teal	0.334*	0.438***	−0.360**	0.122	0.162	0.388**
Northern shoveler	0.393**	0.476***	−0.490***	−0.051	0.246	0.355**
Gadwall	0.162	0.294*	−0.381**	−0.165	0.285	0.302*
Northern pintail	0.257	0.300*	−0.383**	−0.060	0.226	0.340**
Redhead	0.305*	0.386**	−0.183	0.223	−0.094	0.188
Ruddy duck	0.329*	0.316*	−0.258	−0.031	0.024	0.147
Dabbling ducks	0.263	0.420**	−0.381**	0.141	0.229	0.474***
Diving ducks	0.354**	0.422**	−0.227	0.175	−0.054	0.217
Total ducks	0.332*	0.455***	−0.365**	0.135	0.157	0.411**

* Marginally significant ($P < 0.10$).
** Moderately significant ($P < 0.05$).
*** Highly significant ($P < 0.01$).
[1] Ducks observed on at least 50% of the wetlands during one of the post-treatment years.

er in wetlands with relatively high proportions of open water and dead vegetation, whereas their numbers were lower in wetlands dominated by live vegetation. Numbers of diving ducks were clearly related to the proportion of open water in the wetlands. A combination of open water, live vegetation, and decaying vegetation probably provides ideal habitat for aquatic invertebrates that may be available to foraging waterfowl (Murkin et al. 1982). Additionally, a combination of live and dead emergent vegetation provides visual isolation for breeding pairs of conspecifics (Murkin et al. 1982) and concealment for broods (Stoudt 1971). Dead emergent vegetation also provides nest sites for over-water nesting ducks (Stoudt 1971, Krapu et al. 1979, Arnold et al. 1993).

The current recommended glyphosate application rate is 5.3 l/ha (Linz et al. 1995), and treatment effects can last ≥ 4 years when water levels remain at 30 cm or deeper (Solberg and Higgins 1993, Linz et al. 1995). Cattails standing in shallow water will likely regrow within two years, thus providing nesting and escape cover for ducks (Stoudt 1971, Krapu et al. 1979, Arnold et al. 1993), resident game birds (e.g., ring-necked pheasant, *Phasianus colchicus* L.), migrating birds (Stromstad 1992, Blixt 1993, Linz et al. 1994), and mammals (Fritzell 1989).

SUMMARY AND RECOMMENDATIONS

Our investigation supports Solberg and Higgins (1993) conclusion that waterfowl use of wetlands can be increased by creating openings in the wetland canopy with glyphosate. However, increased use of a managed wetland by ducks does not necessarily mean that ducks nesting over water have enhanced success. Fragmentation of dense cattail stands may increase the vulnerability of over-water nesting ducks to predators foraging on the wetland edge (Johnson et al. 1989, Greenwood et al. 1995). It appears the 50% sprayed wetlands harbored more ducks than the 70% sprayed and 90% sprayed wetlands. However, we caution that cattails quickly regrow in areas of the wetland that do not maintain adequate water depth (>30 cm) to suppress regrowth from seeds (Merendino and Smith 1991). Thus, treating at least 70% of the emergent vegetation may be necessary to maintain sufficient open water over several years. On the other hand, wetland managers may choose periodically to treat wetlands to maintain the desired ratio of open water, live vegetation, and dead vegetation. Drastic reductions (>90%) of emergent vegetation in deep-water zones of a wetland may severely retard the rate of regeneration of emergent vegetation by vegetative reproduction and, thus, may reduce the number of breeding ducks using the wetland.

We agree with Weller (1978) and Kantrud (1986) that experimental research on the optimal size, configuration, and density of vegetation patches in relation to water-depth and coverage is needed before definitive recommendations can be made regarding habitat manipulations designed to increase waterfowl use of wetlands.

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